Anthropometric Measurement and Comparative Analysis of Ethiopian Army Personnel Across Age, Ethnicity, and Nationality

Amare Wibneh, Ashish Kumar Singh, and Sougata Karmakar*

Department of Design, Indian Institute of Technology Guwahati, Guwahati - 781 039, India
*E-mail: karmakar.sougata@gmail.com

ABSTRACT

The anthropometric characteristics of the users depend upon the topography, nutrition, age, ethnicity, gender, and living conditions, and play a crucial role in the design of the equipment and the workspace to be used by them. This study aims to establish an anthropometry database for male Ethiopian army personnel and investigate the anthropometric variability across ethnicity, age, and with other countries, with the intention to facilitate ergonomic design and development of various facilities (e.g., equipment/ devices, and workspaces) for the Ethiopian army. Following the reliability assessment of the physical measurement technique, the anthropometric data from 250 Ethiopian male army personnel (four different ethnic groups at different age levels) were collected, and normality of the data set was tested. The anthropometric database of Ethiopian army personnel in terms of range, mean, standard deviation, percentile values (5th, 50th, and 95th) was documented. PCA was applied to select a smaller representative by reducing a larger set of variables for further statistical analysis and applications. ANOVA and follow-up *posthoc* test (Tukey's HSD test) were carried out to compare anthropometric differences among different age groups and ethnic variations. The mean anthropometric differences were also compared with databases from other countries (India, Korea, and USA) using t-test. Significant variations were found when the anthropometry was compared between age, ethnicity, and cross-nationals. The findings indicate that variations in age, ethnicity, and geographical factors could have a significant impact on the ergonomic design of equipment and workspaces of Ethiopian army personnel.

Keywords: Body dimension; Physical measurement; Ergonomic design; Army workspace; PCA

1. INTRODUCTION

Anthropometry has been considered an essential factor for product design, hand tools, and the workplace to increase the worker's comfort, efficiency, and safety[1]. In the present era, user-centric design for the specific users considering anthropometric and range of motion variability is highly desirable[2]. Many researchers[3-5] agreed that anthropometric measurements for the targeted user population play a vital role in designing ergonomic solutions.

In the present era, user-centric design for the specific users considering anthropometric and range of motion (ROM) variability is highly desirable. Developing such anthropometric database is rather common in many other countries of the world[6,7]. Due to the diverse anthropometric characteristics, it is crucial for every country to build its anthropometric database. It helps in resolving variations in body sizes that may occur due to different reasons such as topography, nutrition, ethnicity, gender, and living conditions[8].

Nowadays, most of the armies also produce their military clothes, weapons, and equipment according to the anthropometric characteristics of their soldiers[9]. Since the early 19th century, many anthropometric databases for the army population have been measured in different parts of the world. Countries like Sweden, USA, and Latin-American countries have their updated anthropometric database for their army by diversifying the effects that occurred by factors like age, gender, ethnics, geographical differences[3,10,11], etc. Similarly, the development of anthropometric data for specific users of facility design in Asian countries is not new for the implementation in arm forces[12-14]. These databases were used for the ergonomic design of equipment, clothes, tools, and workspaces for the armed forces[14].

Based on the literature survey, it was found that extensive research on developing an anthropometric database and its applications for ergonomic designs of equipment/ products/ facilities for army personnel are general practices in developed countries, but the same has not got its due attention and importance in Ethiopia. The Ethiopian army employs more than 200,000 army personnel[15]; however, no anthropometric database is available to date. Miss-match between the size of the equipment and workspace to the Ethiopian army is merely common due to the unavailability of the anthropometric database. Unavailability of the anthropometric data for Ethiopian army personnel makes it impossible for ergonomic evaluation and thereby design modification of existing workspaces or equipment/ devices used by them. It is also true that the unavailability of anthropometric data of the Ethiopian army also hinders in conceptualising and designing new

workspace and devices of defence requirements. Therefore, there remains a need for developing an anthropometric database for the Ethiopian army population.

The effect of lifestyle, geographical factors, ethnicity, and social and economic environments may exhibit significant dissimilarity in body sizes[16]. The nutrition level/ living facilities provided to the soldiers of countries like America make their physique comparatively better than soldiers from other countries. Thus, generally, they have larger body sizes[17], whereas Asian people (including army population) have a smaller body size (particularly in limb measurement) in comparison to American people due to geographical diversity[16]. Thus, it is essential to understand the difference in anthropometric data of Ethiopian army personnel with other national databases, so that the design of products and workplaces used by soldiers can be improved.

The collected anthropometric data of Ethiopian army personnel can be predominantly used for the ergonomic design of workspaces and equipment of defence requirements of Etiopia[18,19]. The respective anthropometric measurements acquired from this study may help in designing the army vehicular workspace (Fig. 1):

- The crew seat dimensions viz. seat height, width, depth, headroom height can be determined by popliteal height, hip breadth, buttock-to- popliteal length and sitting height, respectively[20].

- Gunners workspace dimensions viz. height of sight device for a seated gunner, height of sight device for a standing gunner, top hatch diameter, turret handle distance, turret handle height can be determined with respective measurements of sitting eye height, standing eye height, elbow to elbow breadth, the combination of upper arm length and forearm grip length long with ROM, combination of elbow rest height and upper arm length along with ROM[21].

- Driver workspace dimensions viz. control dashboard distance from the scapula rest, steering wheel clearance, control dashboard clearance, pedal distance can be determined with respective measurements of thumb tip reach length, thigh thickness, buttock-to- knee length and combination of buttock-to-popliteal length and popliteal height along with ROM[22].

This study aims to develop an anthropometry database for Ethiopian male army personnel that is intended to be predominantly used for army vehicular workspace design. We investigated the anthropometric variability across ethnicity, age, and other countries. It is envisaged that the developed database would help in the design and development of equipment, devices, vehicles, and any other facilities for the Ethiopian army. Moreover, designers/ engineers may refer to
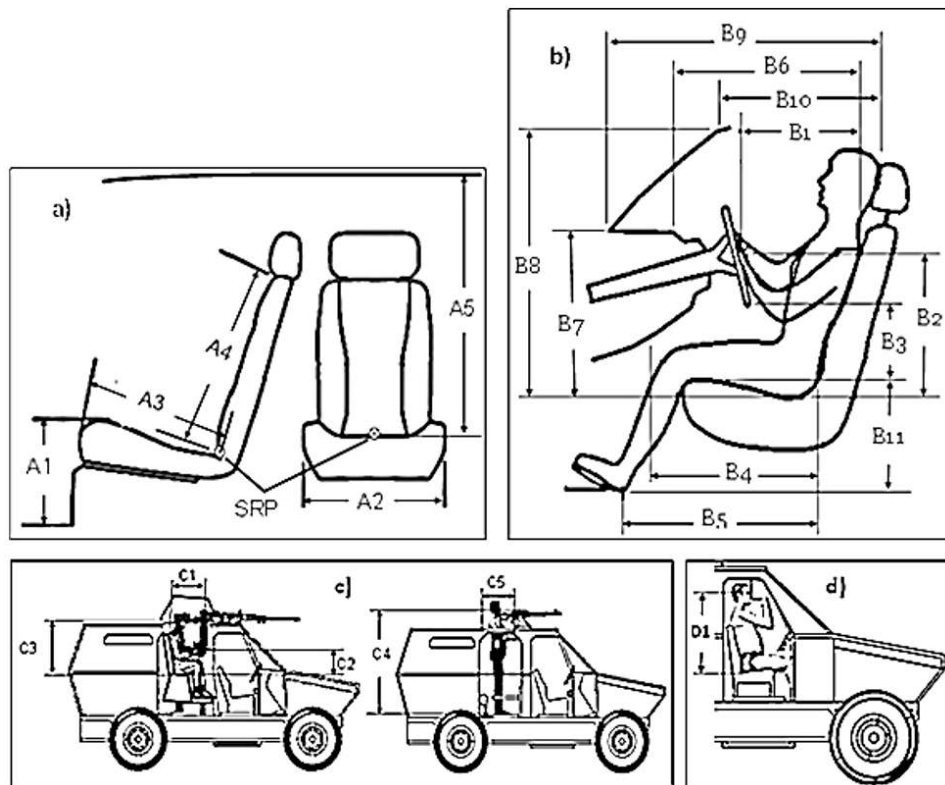

Figure 1. Anthropometric related workspace dimensions of army vehicles (a) Crew seat, (b) Driver workspace, (c) Gunner workspace in sitting posture and standing posture, and (d) Commander workspace (Adapted and compiled from: Reed, 2000; Halder, 2017; Tank archive 2013).

Note. A1= crew seat height (other than driver seat height); A2 = seat width; A3 = seat depth; A4 = back rest height; A5 = head room height; B1 = steering wheel distance; B2 = steering wheel height; B3 = steering wheel clearance; B4 = control dashboard clearance; B5 = pedal distance; B6 = control dashboard distance; B7 = cowl point height; B8 = Daylight opening height; B9 = Cowl point distance; B10 = Daylight opening distance; B11 = driver seat height; C1 = turret handle distance; C2 = turret handle height; C3 = height of sight device for seated gunner; C4 = height of sight device for stood gunner; C5 = top hatch diameter; D1 = height of sight device for commander.

this anthropometric database for addressing the region-specific sizing of the equipment and workspaces.

2. METHODOLOGY

This section consists of sample size calculation, anthropometric measurement procedures, selection of the required body variables, and data analysis techniques.

2.1 Participants and Sample Size Determination

The target population for this study was the Ethiopian male army personnel. The participants were randomly selected from the ground forces and, distributions of their age and ethnicity were documented. A total of 250 male armed personnel participated in this study. The participants, aged between 18 and 52 years (mean = 30.86; SD = 6.7) were included. During the recruitment of soldiers to join the army, stature and mass were considered as the main selection criteria. Therefore, the collected anthropometric data of army personnel could not represent the general population, even though the soldiers were selected from the civilian population. Based on the proportion of army population distribution, the participants were selected for the measurement in each ethnic and age group. Therefore, the samples were further divided into these four subgroups to investigate the variability of the anthropometric data among the ethnic groups. The majority of participants belong to Amhara (n=65), Tigray (n=63), Oromia (n=62), and South Region (n=60) of Ethiopia. The rest ethnic regions were not considered in the study due to less number of army populations representing their ethnicity during data collection. Apart from ethnicity, the participants were divided into three groups according to the categories of age (<30 yrs, 30–40 yrs, and >40 yrs) from the questionnaire. The numbers of participants belonging to age categories <30 yrs, 30–40 yrs, and >40 yrs were 108, 82, and 60.

The minimum sample required for a 95% confidence interval for the 5th and 95th percentile was estimated based on ISO 15535:2003 as discussed in Haitao[23], *et al.*, Rahman[24], *et al.* and Shahida[25], *et al.* The minimum required sample size came out to be 56 which is less than the sample size of individual age group or ethnicity. Furthermore, Freud & Perles[26] and Hogg & Tanis[27] have stated that the sample size of the mean larger than 30 can be assumed as normally distributed. This sample size has been calculated based on the following formula:

$$N \geq \frac{(3.006 * CV)^2}{\alpha^2}$$

where N is sample size required; CV is the coefficient of variation ($CV = 25$); α is the percentage of relative accuracy desired ($\alpha = 10\%$) for a 95% confidence interval for the 5th and 95th percentiles.

2.2 Equipment used and Measurement Procedure

The GPM, Switzerland made standard anthropometric set used by Hsiao[28], *et al.* was used in addition to other instruments for anthropometric measurements. The particular standard anthropometric instruments used in this study, were anthropometer (expandable to 2100 mm), sliding calipers (measuring range 0-250 mm and 0-600mm), spreading caliper (measuring range 0 - 3000 mm), a weighing scale (maximum

capacity: 136kg; Model: Equinox BR-9201; Make: Indian) and a steel measuring tape (3000 mm). Adjustable stool for measuring in sitting posture was also used for adjusting the height according to the subjects' preferences[25].

Anthropometric measurements followed the previously published ISO standards, books, and literature protocol[28-33]. The identification of landmarks on body segments was the prior task during measurement. The measurement was taken from the subject with barefooted and light clothing. Participants were told to stand and sit in proper posture, looking forward without body flection, extension, and twisting during the measurement. All body dimensions were measured to the nearest 0.1 cm precision (weight was measured to the nearest 0.1 kg).

2.3 Ranges of the Measured Variables

Though an adequate description of the human body measurement may require over 300 dimensions[32], the scope of this study was limited to measurement of 32 static anthropometric dimensions (including mass) for army equipment and workspace design as shown in Fig. 2. These typical anthropometric variables were adopted from the recommendations for the book of 'Body Space for Design of Work'[32] and Defence standard of 'Using Anthropometry in Designing for Enhanced Crew Performance'[34] as discussed by Ross[35]. The respective descriptions of different body parts are also defined by Pheasant[32] in his book.

2.4 Reliability Assessment

Before conducting the actual experiment, a pilot study was carried out in order to test the precision or reliability of the repeated anthropometric data collected by the inter-observers. Two different observers measured the same subjects from a sample of 20 volunteers (taking 13 body variable measurements from each volunteer), and a reliability test was carried out using the technical error of measurement (TEM). The coefficient of reliability (R) or precision was used to estimate the similarity of repeated measurements by two different observers to ensure the further collected data are supposed to be free from measurement error. The same approach was followed by Stomfai[36], *et al.* to estimate the reliability of anthropometric measurements. Many researchers considered the value of R > 95 % for error-free of their measurements[37-39]. In the present study, we have not included the data from the pilot experiment.

2.5 Statistical Analysis

The anthropometric data representing Ethiopian army body dimensions were developed and statistically analysed using IBM SPSS version 25 software with confidence levels set to 0.05 and 0.01. A variable reduction technique called principal component factor analysis (PCA) was used to group the dimensions into higher-order categories[40-41]. Therefore, a smaller subset of the 14 most influential/ extensive variables was selected from all 32 anthropometric dimensions of 250 male participants. These key anthropometric dimensions which are representative for 32 variables were selected based on their factor loadings and commonality value of PCA analysis. Furthermore, the majority of dimensions that could reliably be represented by dominant variables were dropped from the list
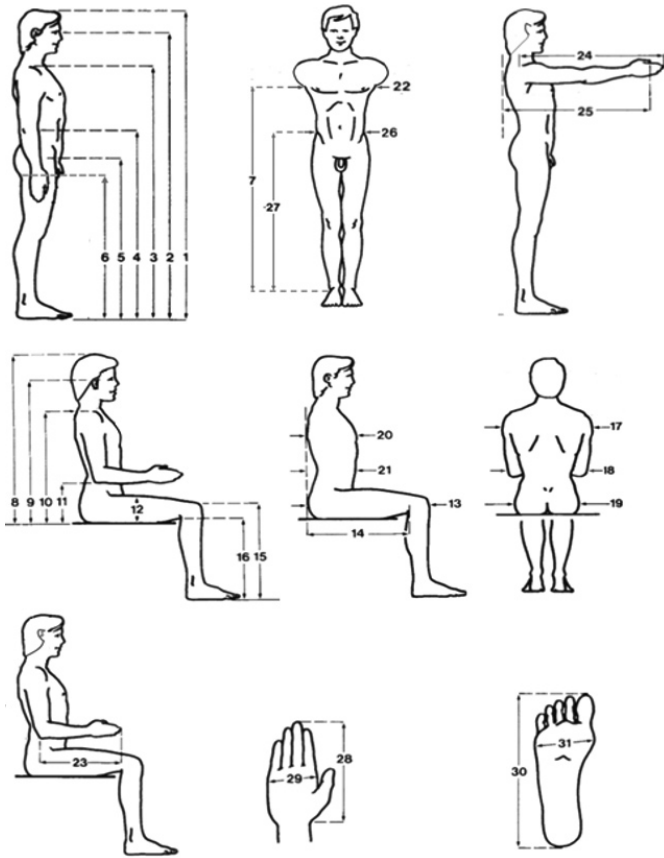
Figure 2. Anthropometric variables in standing and sitting posture *(Adapted from Pheasant, 2005).*

Note

1	Stature	17	Bideltoid breadth
2	Eye height	18	Elbow to elbow breadth
3	Acromial height	19	Hip breadth
4	Elbow height	20	Chest depth
5	Hip height	21	Abdominal depth
6	Buttock height	22	Chest breadth
7	Chest height	23	Forearm length
8	Sitting height	24	Arm length
9	Sitting eye height	25	Thumb tip reach length
10	Sitting acromial height	26	Waist breadth
11	Elbow rest height	27	Waist height
12	Thigh thickness	28	Hand length
13	Buttock to knee length	29	Hand breadth
14	Buttock to popliteal length	30	Foot length
15	Sitting knee height	31	Foot breadth
16	Popliteal height	32	Mass

of key anthropometric dimensions. Finally, the comparison of anthropometric difference among the different ages and ethnic groups were analysed using ANOVA and follow-up *posthoc* tests[42]. Considering all the 32 anthropometric dimensions (including less important physical dimensions) for analysing and interpretation of ANOVA posthoc multiple comparisons results is arduous and unnecessary. Comparison test of the present Ethiopian armed personnel anthropometry with other world countries was carried out using the two-sample t-test.

3. RESULTS AND DISCUSSION

This section mainly includes anthropometric data descriptive along with other investigation results, viz. reliability test of the measurement, and normality of anthropometric data, and lastly, the comparison of anthropometric data in variations of age, ethnics, and the country-wise population.

3.1 Reliability Measurement

TEM, %TEM, and R-values of the inter-observers for a pilot study of 20 volunteers (taking 13 body variable measurements from each volunteer) were presented in Table 1.

As evident from Table 1, TEM, %TEM, and R values for inter observers' measurements ranged from 0.02–0.63, 0.05–1.59, and 0.951–1.000, respectively. All the anthropometric measurements are higher than 0.95 in reliability value or 95% error-free or accurate. Many researchers[38,43] agreed that the 0.95 of reliability is an adequate value to accept though there is no restriction to this value for acceptance or rejection. Since the reliability of our pilot study was greater than 95%, the physical measurement for the main survey (including more participants) would be expected trustworthy and accurate.

Table 1. Reliability test for the variability of inter–observers measurement (n = 20).

Body dimensions (cm)	Inter-observers		
	TEM (cm)*	%TEM*	R*
Bideltoid breadth	0.02	0.05	1.000
Elbow rest height	0.18	0.76	0.994
Forearm length	0.48	1.01	0.976
Hand length	0.27	1.34	0.951
Hand width	0.08	0.95	0.988
Popliteal height	0.33	0.73	0.954
Popliteal length	0.63	1.26	0.969
Buttock to knee length	0.49	0.80	0.973
Foot length	0.23	0.92	0.976
Sitting hip breadth	0.13	0.33	0.997
Thigh thickness	0.10	0.59	0.995
Waist breadth	0.49	1.59	0.960
Waist depth	0.44	1.58	0.972

TEM is technical error of measurement; %TEM = relative technical error of measurement; R = coefficient of reliability; *Ulijaszek & Kerr (1999)

3.2 Anthropometric Data and Normality Test

Table 2 shows the descriptive statistics of anthropometric measurements for male Ethiopian soldiers. The anthropometric database of Ethiopian soldiers for military workspace design was developed in terms of range, mean, standard deviation, percentile values (5th, 50th, and 95th). The body mass index (BMI) was also calculated and reported in Table 2. The mean BMI was also found to be 21.95 kg/ m^2 and is within the normal range of 18.5–24.9[44]. The normality of the data distributions was also tested using skewness and kurtosis tests for validating the nature of data distributions representing the army population[42], as shown in Table 2. If the ratio of skewness and kurtosis to their standard error (Z-scores) lie between -2 and 2, then the respective distribution could be considered normal[45-47].

Table 2. Anthropometric data for Ethiopian male army population (n = 250) with normality test

	Anthropometric Variables	Mean	SD	Percentile			95%CI		Normality test	
				5th	50th	95th	LB	UB	Skewness Z-score	Kurtosis Z-score
Standing Posture										
1	Stature	170.34	6.40	161.00	169.50	179.90	169.23	171.00	1.57*	-1.10*
2	Eye height	159.83	6.40	150.60	159.00	168.90	158.74	160.48	1.28*	-1.20*
3	Acromial height	140.86	5.60	132.50	140.00	149.00	139.85	141.40	1.99*	-1.32*
4	Chest height	131.22	4.90	117.50	125.00	134.50	124.45	125.97	1.87*	-0.96*
5	Elbow height	108.22	4.90	101.00	108.00	116.00	107.37	108.73	1.92*	-1.39*
6	Waist height	96.96	5.60	87.10	96.00	105.00	96.04	97.61	-0.36*	-1.29*
7	Hip height	84.41	5.10	75.50	84.00	91.00	83.58	85.00	0.61*	-0.78*
8	Buttock height	75.91	4.20	68.48	75.58	81.42	75.22	76.41	0.62*	-0.78*
9	Arm length	75.93	3.70	70.00	75.50	81.90	75.31	76.34	0.34*	-1.56*
Sitting Posture										
10	Sitting height	85.01	3.6	79.77	84.60	90.86	84.35	85.38	1.28*	-1.51*
11	Eye height	73.80	4.0	67.48	73.35	80.20	73.12	74.20	1.15*	-1.71*
12	Acromial height	58.69	3.4	52.71	58.18	64.15	78.12	79.04	0.66*	-1.23*
13	Elbow rest height	21.74	2.9	17.20	21.75	26.31	21.32	22.13	0.94*	-0.65*
14	Thigh thickness	15.89	1.1	14.33	15.74	17.68	15.73	16.02	3.36	-1.11*
15	Bideltoid breadth	45.31	1.9	42.34	45.00	48.58	45.01	45.55	0.78*	-1.42*
16	Elbow to elbow breadth	50.19	2.6	46.21	49.77	54.55	49.77	50.50	0.70*	-1.45*
17	Chest breadth	29.41	1.7	29.00	31.00	34.00	31.06	31.50	1.86*	-1.49*
18	Chest depth	23.27	2.6	23.38	26.03	30.02	26.14	26.74	1.96*	-0.59*
19	Waist breadth	29.41	1.7	27.10	29.00	32.90	29.14	29.60	2.96	4.53
20	Abdominal depth	23.27	2.6	19.53	22.60	28.44	22.84	23.57	2.33	-0.25*
21	Hip breadth	37.03	2.28	34.50	36.50	40.90	36.68	37.23	3.4	2.75
22	knee height	54.13	2.9	50.83	54.16	57.16	54.02	54.58	-0.35*	-1.14*
23	Popliteal height	43.56	2.5	40.35	42.58	47.81	43.13	43.80	2.00*	-1.62*
24	Buttock to popliteal length	48.54	2.1	44.99	48.90	50.86	48.17	48.75	-0.25*	-2.19
25	Buttock to knee length	61.18	2.4	57.35	60.71	64.25	60.78	61.44	0.83*	-1.51*
26	Forearm length	45.83	3.3	41.10	45.50	50.40	45.29	46.12	1.99*	-1.78*
27	Forward thumb tip reach	81.25	3.9	75.33	80.82	87.27	80.60	81.69	0.81*	-0.15*
Standing/ Sitting Posture										
28	Hand length	18.45	1.4	16.52	18.29	20.70	18.20	18.55	2.00*	-0.32*
29	Handbreadth	8.40	0.70	7.41	8.33	9.50	8.28	8.46	1.98*	-0.48*
30	Foot length	25.21	0.90	23.50	25.00	26.50	25.06	25.31	-0.28*	0.23*
31	Foot-breadth	9.55	0.40	8.77	9.50	10.00	9.48	9.60	-4.54	-1.69*
32	Mass (kg)	66.75	9.4	55.00	65.00	84.00	65.16	67.70	3.21	-1.53*
	BMI (kg/m^2)	23.00	2.61	21.2	22.6	25.4	22.75	23.15		

All measurements are in cm unless specified; CI = confidence interval; LB = lower bound; UB = upper bound; BMI = body mass index.

* The data is a normal distribution

As evident from Table 2, skewness Z-score depicted that the majority (81%) of the body variables could be considered normal. Similarly, kurtosis Z-score depicted that only three body variables, i.e., popliteal length, hip breadth, and waist breadth were not normal, while the rest (90% body variables) could be considered normal. Brolin[44], *et al.* and Taifa and Desai[47] pointed out that stature and other limb measurements are often normal, irrespective of small sample size. In related literature[48,49], it has been documented that most of the anthropometric variables are normally distributed, even for smaller sample sizes; however, body weight often show a positively skewed distribution. Our study also reports similar inferences about the distributional patterns.

3.3 Principal component factor analysis

To tackle the difficulty of analysing and interpreting large numbers of variables and levels in a data set, various variable reduction techniques such as decision tree and PCA can be used for clustering and identifying the most important factors/variables[50, 51]. For this particular study, PCA concepts have been utilised before further analyses. During this study, the highly inter-correlated anthropometric variables were grouped into six factors, as shown in Table 3. Estimated factor loadings and communality results could be used to define each factor. These six factors were constructed to achieve minimum effective data values that will account for the maximum variances in the data for the particular multivariate analysis.

Table 3 shows the criteria for the selection of variables under the component loading factors. Variables with loading factor coefficient and commonality greater than 0.60 and 0.70 respectively were clustered in each factor. The most considerable portion of variation (50.2%) was accounted for by the first factor, and nearly 35.8% of the total variance was distributed in the remaining ones. The anthropometric variable having maximum factor loading value and commonality gets the preference for grouping under the respective component factor. For example, although the factor loading coefficient of stature was higher than 0.60 for factors 1 and 3, it was considered under factor 1 (Fac01).

14 variables were considered to be the most influential ones. These variables include six dimensions viz. stature, hip breadth, arm length, sitting height, bideltoid breadth, and foot length. These dimensions would be considered the most essential/ dominant dimensions (with the highest factor loading coefficient and commonality in each component factor category) in terms of physical characteristics of the Ethiopian army. These six variables are expected to have nearly similar characteristics of variances in each component factors[52] and account for a considerable portion of the total variance. Earlier studies have also shown that the dominant variable can represent other variables within the group[53]. It is worth noting to consider variables that are not represented by other variables or not a part of any component factor category. Therefore, among the 14 influential variables, we have also considered popliteal height and popliteal length, having low recommended communality values (< 0.70) yet high factor loading coefficients as shown in Table 3. Since there is no maximum restriction to extend the number of dimensions, six

other targeted variables have also been included for their relative importance based on previous literature. These variables were mass, thigh thickness, abdominal depth, waist breadth, thumb tip reach length, and sitting eye height. The aforementioned 14 influential dimensions was further analysed graphically and statistically among different age and ethnic groups.

3.4 Anthropometric Data Variations on Age, Ethnicity, and Comparison with other Country Population

3.4.1 Comparison of Present Anthropometric Data among Age and Ethnic Groups

Among 32 anthropometric variables, the 14 key variables were analysed using both ANOVA and graphical methods. Figure 3(a), and Table 4 show the comparison of different age groups (<30 yrs, 30-40 yrs, and >40 yrs) with a sample size of 108, 82, and 60. In Fig. 2(a), the AG1 age group (< 30 yrs) was taken as a reference to the other age groups (AG2 = 30 - 40 yrs and AG3 = >40 yrs) for the group comparison. The mean difference and its significance were also studied thoroughly later in the text.
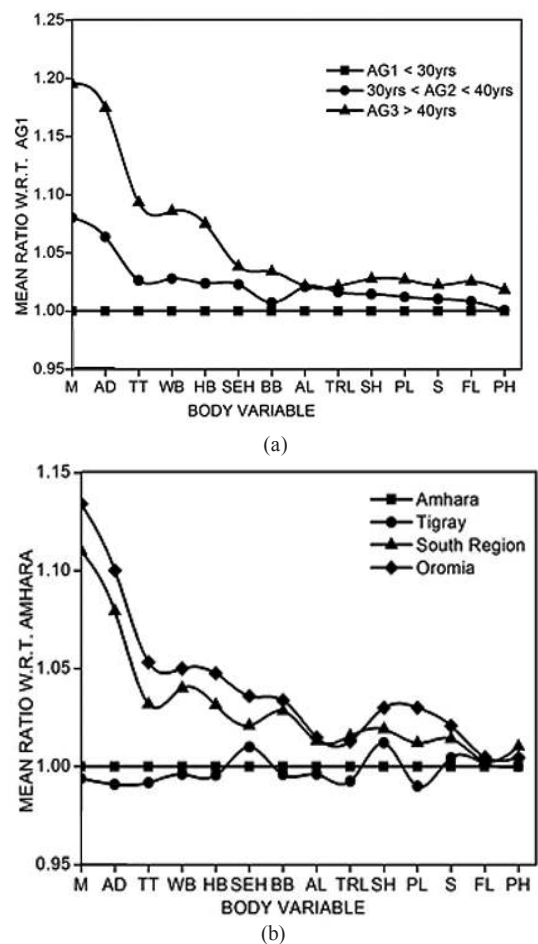

(a)

(b)

Figure 3. Comparison of the anthropometric mean for (a) age groups and (b) ethnic groups

Note: M-mass; AD-abdominal depth; TT-thigh thickness; WB-waist breadth; HB-hip breadth; SEH- sitting eye height; BB-bideltoid breadth; AL-arm length; TRL-thumb tip reach length; SH-sitting height; PL-popliteal length; S-stature; FL-foot length; PH-popliteal height.

Table 3. Factor loadings and communality results for the anthropometric dimensions (satisfying the eigenvalue ≥1 criterion)

Anthropometric Variables	Component factors						
	Fac01	Fac02	Fac03	Fac04	Fac05	Fac06	Commonality
Stature	**.949***	.540	.751	.474	.588	.575	.927#
Acromial height	**.944***	.600	.703	.491	.543	.517	.923#
Standing eye height	**.939***	.572	.728	.512	.610	.558	.919#
Buttock height	**.909***	.348	.536	.366	.422	.423	.882#
Hip height	**.908***	.349	.535	.366	.421	.422	.881#
Chest height	**.902***	.581	.641	.492	.516	.518	.852#
Standing elbow height	**.896***	.590	.677	.488	.452	.549	.878#
Waist height	**.893***	.374	.606	.333	.489	.499	.816#
Knee height	**.835***	.428	.607	.248	.401	.375	.714#
Popliteal height	**.805***	.284	.565	.229	.293	.324	.690
Buttock to knee length	**.760***	.592	.673	.074	.525	.487	.756#
Popliteal length	**.727***	.503	.620	.021	.462	.474	.686
Bideltoid breadth	.472	**.899***	.710	.283	.347	.354	.864#
Elbow to elbow breadth	.471	**.897***	.702	.283	.346	.353	.862#
Chest depth	.342	**.878***	.702	.392	.395	.479	.837#
Chest breadth	.334	**.867***	.609	.372	.252	.479	.835#
Foot breadth	.428	**.625***	.597	.210	.196	.300	.713#
Hand breadth	.257	**.607***	.560	.140	.192	.269	.702#
Sitting hip breadth	.465	.634	**.964***	.347	.349	.316	.938#
Abdominal depth	.481	.625	**.963***	.362	.354	.341	.932#
Waist breadth	.435	.646	**.958***	.311	.343	.315	.931#
Thigh Thickness	.483	.611	**.946***	.308	.347	.362	.895#
Mass	.520	.772	**.824***	.516	.327	.490	.824#
Sitting height	.572	.465	.375	**.892***	.568	.403	.866#
Sitting eye height	.589	.403	.452	**.877***	.576	.437	.867#
Sitting acromial height	.535	.327	.392	**.866***	.517	.419	.828#
Elbow rest height	.428	.182	-.112	**.802***	.454	.093	.823#
Arm length	.608	.294	.180	.539	**.963***	.517	.952#
Forearm length	.591	.283	.171	.500	**.956***	.608	.945#
Sitting thumb tip reach	.678	.372	.170	.580	**.895***	.451	.901#
Foot length	.556	.322	.328	.429	.484	**.931***	.951#
Hand length	.544	.280	.285	.504	.445	**.834***	.938#
Eigenvalue	**16.555**	**4.641**	**2.607**	**1.856**	**1.649**	**1.056**	**---**
Total Variance (%)	**50.167**	**14.062**	**7.900**	**5.626**	**4.996**	**3.199**	**---**
CV (%)	**50.17**	**64.23**	**72.13**	**77.76**	**82.75**	**85.95**	**---**

CV = Cumulative of Variance; #Communalities ≥ 0.70; *Factor loading ≥0.60

As clearly shown in Fig. 3(a), the age group of > 40 yrs was recorded as the higher mean difference in anthropometric measurement. Furthermore, the mean differences between the three age groups are high, particularly for mass, breadth, depth, and thickness. Therefore, it can be concluded that the girth variables (breadth, thickness, depth, and weight) are the major variables that are affected by these age variations. Similar to our results, in an anthropometric study by Samuel[49], *et al.* and McDowell[54], *et al.*, it was also observed that as age increases, the body size (mass, breadth, depth, and thickness) also increases to the certain extent.

Table 4 depicts that there was a significant change in all the anthropometric measurements among the three age categories at a significant level of 0.05 except popliteal height. McDowell[54], *et al.* categorised the age levels and opined that the mass increases significantly up to the age of

Table 4. ANOVA statistics for comparison among the three age groups (<30 yrs, 30-40 yrs and >40 yrs) of army personnel

Anthropometric Variables	Mean(SD)			Mean square	F value	p value
	AG1	AG2	AG3			
Mass (kg)	62.2 (6.6)	67.4 (8.5)	74.6 (8.9)	1721	27.42	.000**
Stature	168.6 (5.0)	170.2 (5.8)	172.2 (6.2)	172	4.46	.013*
Sitting height	83.9 (3.4)	85.1 (3.5)	86.1 (3.5)	70	5.34	.006**
Sitting eye height	72.4 (3.5)	74.1 (3.7)	74.6 (8.9)	108	7.86	.001**
Arm length	74.7 (3.2)	76.4 (3.3)	76.5 (3.6)	59	4.52	.012*
Thumb tip reach	80.1 (3.3)	81.5 (3.6)	80.1 (3.8)	51	3.52	.032*
Popliteal length	47.9 (1.8)	48.5 (2.0)	49.1 (1.7)	20	4.84	.009**
Popliteal height	43.3 (2.27)	43.3 (2.2)	44.1 (1.8)	8	1.37	.256
Bideltoid breadth	44.6(1.7)	44.8(1.5)	45.9(1.9)	73	23.44	.000**
Abdominal depth	21.9 (0.2)	23.4 (2.4)	25.9 (2.5)	171	34.83	.000**
Waist breadth	28.6 (1.1)	29.4 (1.6)	31.1 (1.6)	69	33.83	.000**
Hip breadth	36.1 (1.4)	36.9 (1.8)	38.8 (1.9)	84	28.45	.000**
Thigh thickness	15.5 (0.8)	15.9 (1.0)	16.9 (1.1)	24	27.60	.000**
Foot length	25.0 (0.6)	25.2 (0.9)	25.6 (0.9)	5	6.00	.003**

All measurements are in cm unless specified; **(p<0.01); *(p<0.05)
AG1=Age group 1 (<30 yrs); AG2=Age group 1 (30-40 yrs); AG3=Age group 1 (>40 yrs)

60 years and then tends to decrease. Unlike mass, the stature measurements have no specific trend and may either decrease or increase in each age group. Our results showed that there was a high variation in variables other than limb measurements among the age groups. Therefore, the anthropometric data of the army personnel shall be developed for each age group as long as significant variation exists among them.

Following the ANOVA analysis, Tukey's HSD *post-hoc* comparisons were conducted to investigate the pairwise significance among the three age groups, as shown in Table 5. As apparent, the majority of the selected anthropometric variables have significant mean differences among the age groups. It was evident that with growing age, the anthropometric variables like mass, and breadth measurements were also increasing. However, no effect of age was observed on the limb measurements.

Samuel[49], *et al.* studied the effect of age on anthropometric measurements among 120 Gari frying workers in Southwest Nigeria. They pointed out that the mass, BMI, and majority of girth measurements significantly increase as the age increases up to the age of 55 yrs. Our study reports similar implications about the effect of age on anthropometric measurements among the Ethiopian armed personnel. Hence, designers need to use appropriate anthropometric data according to the target age group. Practicing wrong anthropometry in designing the work system may result in an unsafe workplace, which in turn, affects user comfort and efficiency.

While comparing anthropometry w.r.t ethnicity, the Amhara region was taken as a reference for the group comparison, as shown in Fig. 3(b). The sample sizes in regions of Amhara, Tigray, Oromia, and South Regions were 65, 63, 62, and 60, respectively. Table 6 and 7 show the ANOVA and its follow-up posthoc comparisons to test the ethnic difference among the anthropometric variables of soldiers coming from these ethnic regions.

Table 5.   ANOVA *post hoc* multiple comparison (Tukey's HSD test) pairwise comparisons among the three age groups

Anthropometric variables	Mean difference		
	AG1-AG2	AG1-AG3	AG2-AG3
Mass (kg)	-5.01*	-12.20*	-7.19*
Stature	-1.74	-3.75*	-2.01
Sitting height	-1.23	-2.32*	-1.10
Sitting eye height	-1.67*	-2.78*	-1.12
Arm length	-1.56	-1.61	-0.06
Thumb tip reach length	-1.32	-1.73	-0.41
Popliteal length	-0.58	-1.29*	-0.71
Popliteal height	-0.03	0.79	-0.75
Bideltoid breadth	0.5	2.4*	-1.9*
Sitting hip breadth	-0.86*	-2.71*	-1.85*
Abdominal depth	-1.40*	-3.85*	-2.44*
Waist breadth	-0.80*	-2.46*	-1.66*
Thigh thickness	-0.41*	-1.45*	-1.04*
Foot length	-0.20	-0.64*	-0.43

All measurements are in cm unless specified
* The mean difference is significant at 0.05 levels.

As clearly shown in Fig. 3(b), the Oromia ethnic group was recorded as the highest anthropometric measurement as compared to all other groups, whereas, Tigray and Amhara ethnic groups were recorded as the least. Notably, the major anthropometric differences between Oromia and South Region were depicted in mass, breadth, depth, and thickness. Therefore, it concluded that breadth, thickness, and mass are the major variables that are affected by these ethnic group variations.

Table 6 shows the ethnic variation has a significant change in the majority of the presented anthropometric measurements

Table 6. ANOVA statistics for comparison among the four ethnic groups (Tigray, Amhara, Oromia, South Region, and Other ethnic regions) of army personnel

Anthropometric Variables	Mean (SD)				Mean square	F value	*p* value
	Amhara	Tigray	Oromia	South region			
Mass	63.1(7.6)	62.8(6.7)	71.3(10.1)	70.2(8.6)	704.59	10.56	.000**
Stature	168.4(4. 9)	169.5(5.5)	171.4(6.0)	170.0(6.1)	93.72	2.42	.050
Sitting height	83.7(3.0)	84.6(3.3)	85.9(3.4)	84.9(4)	45.59	3.52	.008**
Sitting eye height	72.4(3.6)	73.3(3.4)	74.8(3.5)	73.6(4.2)	55.99	4.06	.003**
Arm length	75.3(3.6)	75.0(3.4)	76.4(3.2)	76.3(3.2)	25.00	1.88	.116
Thumb tip reach	80.6(3.8)	80.4(3.5)	81.8(3.5)	81.6(3.4)	26.39	1.79	.132
Popliteal length	47.9(1.9)	48.0(1.9)	49.2(1.9)	48.3(1.9)	14.57	3.52	.008**
Popliteal height	43.3(2.1)	43.4(2.5)	43.4(2.2)	43.6(2.7)	1.35	.23	.920
Bideltoid breadth	44.7(1.7)	44.6(1.5)	46.2(2.0)	45.9(1.9)	25.65	7.92	.000**
Waist breadth	28.9(1.6)	28.8(1.3)	30.3(1.8)	30.0(1.5)	20.613	8.764	.000**
Abdominal depth	22.3(2.5)	22.2(1.9)	24.5(2.8)	24.1(2.3)	51.98	9.19	.000**
Sitting hip breadth	36.4(1.6)	36.2(1.5)	37.9(2.3)	37.4(1.7)	26.66	8.09	.000**
Thigh thickness	15.6(1.0)	15.5(0.8)	16.4(1.2)	16.0(0.9)	6.90	7.11	.000**
Foot length	25.1(0.9)	25.2 (0.8)	25.2(1.0)	25.1(0.9)	.14	.18	.950

All measurements are in cm unless specified; **($p<0.01$); *($p<0.05$)

at a significant level of 0.05. Stature, arm length, and foot length were the non-significant variables among the selected body variables. However, the other four important variables (mass, sitting height, bideltoid breadth, hip breadth) showed significant variation among the groups. It indicates that the anthropometric data of the army personnel shall be developed for each ethnic group as long as significant variation exists among them. Following ANOVA, the significance of the mean differences within pairwise ethnic groups was reported in Table 7 to investigate the difference among groups.

The result from Table 7 depicts that the Oromia was significantly different in mass and breadth, and sitting height measurements comparing with Amhara. Moreover, South Region measurements were significant for mass, and bideltoid breadth when compared with Amhara. However, no statistical difference was evident between Amhara and Tigray in any of the anthropometric measurements. Oromia has the largest anthropometric measurements among the four ethnic groups.

3.4.2 Comparison of Present Anthropometric Data with International Databases

Anthropometric mean values of the Ethiopian army were compared with other countries like Korea[13], India[14], and USA[55]. Those countries were chosen for comparison test based on the availability of the army anthropometric data and diversity of the population among Western and Eastern worlds[16,17]. The comparison of Ethiopian anthropometric mean values along with its significance with the mentioned countries is shown in Fig. 4 and Table 8.

The result shown in Table 8 depicts the mean anthropometric differences of Ethiopian soldiers compared with other countries' army population like the USA, Korea, and India. The majority of body measurements were statistically significant at 0.05 levels (2-tailed). Generally,
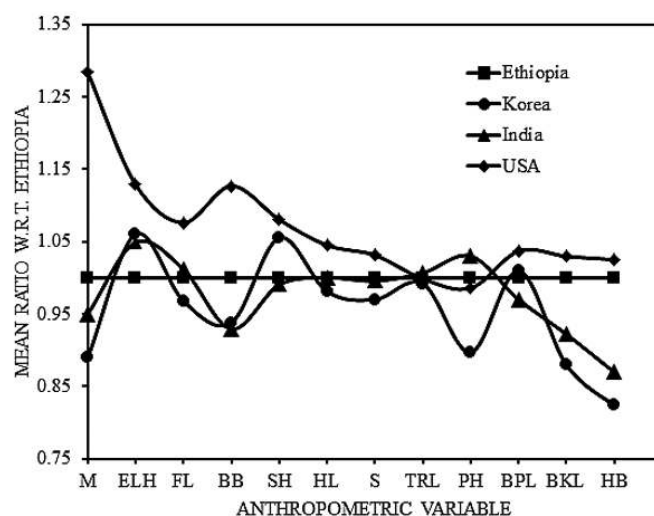

Figure 4. Comparison of the Ethiopian anthropometric mean with three different countries

Note: M-mass; ELH-elbow rest height; FL-foot length; BB-bideltoid breadth; HL-hand length; S-stature; SH-sitting height; TRL-thumb tip reach length; PH-popliteal height; HB-hip breadth; BKL- buttock to knee length; BPL-Buttock to popliteal length.

the Asian countries have the least body size, and all the body dimensions of the USA army are larger than the Ethiopian army (Fig. 4) except thumb tip reach length and hip breadth. In general, these comparative results indicate that the majority of Ethiopian army body sizes are not compatible with those of other countries.

As long as the size of the body varies significantly, the variability has an ergonomic impact on the design of tools, equipment, and workspaces for the army users. In ergonomics design, attention should always be given to the variability of body dimensions[56,57]. For instance, the hip breadth of the Ethiopian army was larger than all the countries reported in

Table 7. ANOVA *post hoc* multiple comparison (Tukey's HSD test) pairwise comparisons among the four ethnic groups

Anthropometric variables	Ethnic groups	Mean difference			
		Amhara	Tigray	Oromia	South region
Mass	Amhara	0.00	0.35	-8.50*	-6.97*
	Tigray	-0.35	0.00	-8.85*	-7.31*
	Oromia	8.50*	8.85*	0.00	1.54
Stature	Amhara	0.00	-0.78	-3.52	-2.41
	Tigray	0.78	0.00	-2.74	-1.63
	Oromia	3.52	2.74	0.00	1.11
Sitting height	Amhara	0.00	-0.91	-2.46*	-1.63
	Tigray	0.91	0.00	-1.55	-0.72
	Oromia	2.46*	1.55	0.00	0.84
Sitting eye height	Amhara	0.00	-0.85	-2.65*	-1.52
	Tigray	0.85	0.00	-1.80	-0.67
	Oromia	2.65*	1.80	0.00	1.13
Arm length	Amhara	0.00	0.48	-2.10	-1.27
	Tigray	-0.48	0.00	-1.68	-1.75
	Oromia	1.19	1.68	0.00	-0.07
Thumb tip reach	Amhara	0.00	0.36	-1.29	-1.43
	Tigray	-0.36	0.00	-1.65	-1.79
	Oromia	1.29	1.65	0.00	-0.14
Popliteal length	Amhara	0.00	0.09	-1.32*	-0.56
	Tigray	-0.09	0.00	-1.41	-0.66
	Oromia	1.32*	1.41*	0.00	0.75
Popliteal height	Amhara	0.00	0.00	-0.20	-0.44
	Tigray	0.00	0.00	-0.21	-0.44
	Oromia	0.20	0.21	0.00	-0.24
Bideltoid breadth	Amhara	0.00	0.16	-1.50*	-1.30*
	Tigray	-0.16	0.00	-1.66*	-1.45*
	Oromia	1.50*	1.66*	0.00	0.21
Waist breadth	Amhara	0.00	0.21	-2.18*	-1.75*
	Tigray	-0.26	0.00	-2.60*	-2.10*
	Oromia	2.23	2.60*	0.00	0.47
Abdominal depth	Amhara	0.00	0.21	-2.18*	-1.75*
	Tigray	-0.21	0.00	-2.40*	-1.97*
	Oromia	2.18	2.40*	0.00	0.43
Sitting hip breadth	Amhara	0.00	0.20	-1.59*	-1.10
	Tigray	-0.20	0.00	-1.78*	-1.30*
	Oromia	1.59*	1.78*	0.00	0.48
Thigh thickness	Amhara	0.00	0.12	-0.83*	-0.49
	Tigray	-0.12	0.00	-0.94*	-0.61*
	Oromia	0.83*	0.94*	0.00	0.34
Foot length	Amhara	0.00	-0.05	-0.13	-0.08
	Tigray	0.05	0.00	-0.08	-0.03
	Oromia	0.13	0.08	0.00	0.05

All measurements are in cm unless specified
* The mean difference is significant at 0.05 levels.

this paper, and thus, the wide ranges of user compatibility products from other countries might not be compatible with the Ethiopian armed personnel.

Except for the study of the anthropometric characteristics done by Odhuno-Otieno[58] among the students from Bahir Dar University (from age 18 to 24 years), there is no other reported study about the establishment of an anthropometric database for Ethiopian civil and army population. Therefore, the current research towards the development of the anthropometric database of the Ethiopian Army population is the first of its kind.

It is expected that baseline information suggested in the present study would be helpful towards for ergonomists and designers designing army equipment and workplaces on the basis of ergonomic considerations. Moreover, it would be useful in curtailing the between miss-match body size and product/ workspace dimensions. The effective design of the army equipment and workspaces takes into account the human body dimensions for the design compatibility of equipment/ workspace[59]. Since the shape and size of the human body can vary significantly due to those factors, the variability has an ergonomic impact on the design of tools, equipment, and workspaces for the user[60]. In some studies[61,62], investigators have proposed that the engineering anthropometry aims to provide accurate body dimensions for obtaining a good fit of a product to the user.

Moreover, the fitness of the Ethiopian army user anthropometry to the product dimension should be considered whenever the defence sector imports the army goods from partners of world countries[63]. Unless the specifications are provided, the equipment manufacturers or suppliers may consider developing the product as per the anthropometric dimension within their respective country[64]. During the present time, the variability of the body sizes between Ethiopia and its partner countries affects the ergonomic compatibility of the products for the intended users in Ethiopia. However, we anticipate that the establishment of an anthropometric database for the Ethiopian army will undoubtedly reduce the variability of the product dimensions and anthropometric characteristics. This anthropometric data development might also be used as the primary input for the main anthropometric data of Ethiopia that will be developed in the future at diverse and extensive levels.

The findings of this anthropometry survey are not without limitation. It must be noted that this study shall not be restricted, conducting only on a small group of army personnel. One should be cautious about using the survey data before further studies. Being the first of its kind, the data can be used as a foundation for future studies. The developed anthropometric data may not be sufficient for designing ergonomic fit uniforms/clothing due to the lack of some required girth/ circumference measurements[10]. Future directions include extending the sample size to achieve a more reliable anthropometric database and conclude the variation effects. The normality test of the data distribution

Table 8. Significant t-test for anthropometric data of Ethiopian male soldiers comparing with other countries

Anthropometric Variables	Ethiopia[#] (n=250) Mean (SD)	USA[55] (n=4082) Mean (SD)	India[14] (n=11,458) Mean (SD)	Republic of Korea[13] (n=3,747) Mean (SD)
Mass (kg)	66.8 (9.4)	85.52 (14.22)*	63.4 (7.42)*	59.4 (4.9)*
Stature	170.3 (6.4)	175.62 (6.86)*	169.6 (5.43)	165.2 (4.9)*
Eye height	159.8 (6.4)	NA	158.3 (5.4)*	NA
Acromial height	140.9 (5.8)	144.07 (6.33)*	141.8 (7.3)*	134.1 (4.7)
Sitting height	85.0 (3.6)	91.83 (3.57)*	84.2 (4.6)*	89.7 (2.7)*
Sitting eye height	73.8 (4)	80.45 (3.32)*	NA	78.2 (3.1)*
Sitting acromial height	58.7 (3.4)	NA	60.7 (3.4)*	58.3 (3.1)*
Sitting elbow height	21.7 (2.9)	24.50 (2.87)*	22.8 (2.6)*	24.8 (1.2)*
Popliteal height	43.6 (2.5)	42.98 (2.48)*	44.9 (2)*	39.1 (2.4)*
Thigh thickness	15.9 (1.1)	18.05 (1.56)*	NA	NA
Buttock to knee length	60.2 (2.4)	61.80 (3.06)*	56.4 (2.6)*	53.8 (2.7)*
Buttock to popliteal length	48.5 (2.1)	50.29 (2.74)*	47.0 (2.6)*	43.0 (2.6)*
Acromial to elbow length	45.8 (3.3)	36.37 (1.82)*	36.3 (1.9)	33.5 (1.9)*
Lower arm length	36.5 (3.1)	48.02 (2.33)*	47.2 (2.2)*	44.0 (2.0)*
Thumb tip reach length	81.3 (3.9)	81.19 (4.37)	81.8 (4.5)	80.6 (4.2)
Bideltoid breadth	45.3 (1.9)	51.04 (3.25)*	42.1 (2.2)*	42.5 (1.9)*
Abdominal depth	23.3 (2.6)	25.47 (3.73)*	NA	NA
Hip breadth	37.0 (2)	36.93 (3.02)	32.2 (1.9)*	30.5 (1.6)*
Hand length	18.5(1.4)	19.33 (0.99)*	NA	18.1 (0.7)*
Hand breadth	8.4 (0.7)	8.83 (0.44)*	8.4 (0.42)	8.5 (0.5)
Foot length	25.2 (0.9)	27.12 (1.31)*	25.5 (1.2)*	24.4 (1.3)*
Foot breadth	9.6 (0.4)	10.19 (0.52)*	9.6 (0.6)	9.6 (0.4)

All measurements are in cm otherwise specific; NA = Not applicable (no information available)
* The mean difference is significant at the 0.05 level (2-tailed).
[#]two-sample t-tests treating this group as a control, and comparing all other groups against it.

we attempted to assess indicates that the majority of the data are normal. Although the data seems normal, it needs an adequate anthropometric data collection survey to represent the army population purely. Experimenting with a large sample size is extremely time-consuming, costly, and difficult[33] unless special support is given by the apprehensive sectors. Moreover, incorporation of anthropometric data of female army personnel is also important as the participation of female in defence services are also increasing with time. Although no attempt was made in current research, it will be interesting to investigate the biomechanical characteristics, body range of motion, and strength capabilities among the army personnel in future studies.

4. CONCLUSIONS

In this work, an attempt was made to develop the anthropometric database for the Ethiopian army population in advance for further investigation of anthropometric variation based on different age levels, ethnic groups, and country-wise comparisons. Following data collection, detailed data analysis was done to ensure reliability and appropriateness of data distribution, the significance of observed differences, and thereby interpretations. The results revealed a significant variation of anthropometric measurements among ages and ethnicity. This study proposes the need for further anthropometric development studies on larger scales. The comparison results showed that the anthropometry of the Ethiopian army varied significantly with respect to other countries. Therefore, this developed anthropometric measurement is highly needed for the ergonomic design of military facilities in Ethiopia to advance user-compatible products and workspaces for specific users.

This research is first of such anthropometry study and thereby initiated the development of an anthropometric database for the male Ethiopian army personnel. Based on the principles of the adequate sample size estimation, it is recommended to include more army personnel in the near future for a much reliable database. Until additional studies, the present anthropometric database may be considered for designing military equipment and workspaces.

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CONTRIBUTORS

Mr Amare Wibneh completed BTech (Mechanical Engineering) and MTech (Industial Design) from Defence Engineering University, Ethiopia. He is currently pursuing PhD in the Department of Design, Indian Institute of Technology, Guwahati, India. He is specialised in ergonomics and his research interests and areas are ergonomics and safety aspects in design and development of army vehicles and equipment, engineering design principles and optimisations, armament engineering, production engineering, and parametric optimisation in quality engineering.
He carried out the ergonomic design analysis of army vehicles for the specific users (Ethiopian army personnel) and he has contributed to reviewing related literature, data collection, performing the statistical analysis, and writing the draft manuscript.

Dr Ashish Kumar Singh obtained his Master's in Quality Management from the Birla Institute of Technology and Science, Pilani. He has earned his PhD in Ergonomics in Design from Malaviya National Institute of Technology, Jaipur. He is a Postdoctoral Fellow in the Department of Design at Indian Institute of Technology, Guwahati, India. His research areas are ergonomics, work system design, human response to vibration, noise exposure, quality, and productivity engineering. He has published more than 20 research articles in various renowned international journals and refereed international conferences.
He has contributed to refining the draft manuscript towards the final one and also helped in selecting appropriate statistical tools for data analysis and interpretation.

Dr Sougata Karmakar did his PhD for his work in the field of 'virtual ergonomics using digital human modelling' from Bharathiar University, India, in 2009. Presently working as an Associate Professor in the Department of Design at Indian Institute of Technology, Guwahati, India. He is associated with 'Ergonomics Laboratory' at Department of Design, IIT Guwahati and continuing his research work in the field of ergonomics/ human factors, safety, and occupational healths in diverse design and developmental set-ups. He has published 30 research papers in journals and 36 research papers in conference proceedings.
He has supervised the overall research work presented in the current paper by providing ideas and guidance in conducting the experiments and writing the manuscript in a systematic way.